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Weak Grip Strength Does not Predict Upper Extremity Musculoskeletal Symptoms or Injuries Among New Workers

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Abstract *Purpose* Grip strength is often tested during post-offer pre-placement screening for workers in hand-intensive jobs. The purpose of this study was to evaluate the association between grip strength and upper extremity symptoms, work disability, and upper extremity musculoskeletal disorders (UE MSDs) in a group of workers newly employed in both high and low hand intensive work. *Methods* 1,107 recently-hired workers completed physical examinations including grip strength measurements. Repeated surveys obtained over 3 years described the presence of upper extremity symptoms, report of physician-diagnosed musculoskeletal disorders (MSDs), and job titles. Baseline measured grip values were used in analytic models as continuous and categorized values to predict upper extremity symptoms, work disability, or UE MSD diagnosis. *Results* Twenty-six percent of males and 20 % of females had low baseline hand strength compared to normative data. Multivariate logistic regression analyses showed no consistent associations between grip strength and three health outcomes (UE symptoms, work disability, and MSDs) in this young cohort (mean age 30 years). Past MSD and work type were significant predictors of these outcomes. *Conclusions* Physical hand strength testing was not useful for identifying workers at risk for developing UE MSDs, and may be an inappropriate measure for post-offer job screens.

Keywords Strength · Occupation · Prediction modeling · Post-offer pre-placement examination

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Introduction

Musculoskeletal disorders are of concern to many employers since they account for 33 % of all injuries and illnesses in 2011 [1] and have high annual costs; the state workers' compensation database in Ohio reported that an average total cost of $128 million is spent on upper extremity musculoskeletal disorders (UE MSDs) annually [2]. The industries with the most frequent number of UE claims were manufacturing followed by service work. As a strategy to reduce worker injuries and associated costs, many companies perform examinations to assess the physical work capabilities of newly hired workers and workers returning to employment following an injury or illness.

Employers often use post-offer pre-placement (POPP) testing to evaluate a worker's physical capability of performing the essential functions of a job [3–5]. This screening is intended in part to identify workers who may be at greater risk of developing future musculoskeletal injuries. Screening tests generally include evaluating worker's physical strength and flexibility before advancing to performance testing of the work-related essential functions of the job [6–8]. A worker who performs the functional activities of the screen and meets the pre-determined criteria is eligible for placement in the available job. Jobs with high physical demands may use functional screening to select workers capable of performing the physical demands of the work tasks. Grip strength is a common measure of physical ability included in POPP screening tests, because it is an estimate of the isometric strength in the upper extremity and an estimation of a worker's overall physical capacity [9–15]. Workers with low muscular strength on lifting or grip tests may not be allowed to advance to the performance testing of the POPP screen. However, current literature contains little evidence concerning the relationship between a worker's physical capacity and the potential risk for developing a musculoskeletal disorder. One cross sectional study among cleaners found that those with better musculoskeletal health had higher muscular strength [16], although a longitudinal study of food production workers found that physical strength did not predict musculoskeletal injuries [17]. A systematic review of longitudinal studies investigating the relationship between lifting strength and neck/shoulder physical capacity and future low back and neck/shoulder musculoskeletal pain reported no conclusive evidence among studies that were available in the literature [18]. There were no studies of distal upper extremity strength in the review.

Post-offer pre-placement screens are relatively common in the hiring process of automotive and other manufacturing industries, in food processing, and more recently in other high risk service jobs such as hospital orderlies. Injury data shows that service, manufacturing, and construction workers are at greatest risk for experiencing upper extremity musculoskeletal injuries. In this longitudinal study, we performed baseline examinations and 3 year follow-up of newly employed workers in three work categories ranging from high to low risk of UE MSDs: construction, service, and office/technical workers. The purpose of this study was to evaluate the association between grip strength and the development of future upper extremity symptoms and musculoskeletal diagnoses among this varied group of workers. This study examined the hypothesis that lower grip strength is associated with a higher frequency of future upper extremity symptoms and the development of new upper extremity musculoskeletal disorders. Conversely, workers with greater grip strength should be less likely to develop upper extremity disorders, and this relationship should especially hold true in more physically demanding jobs.

Methods

We recruited newly-hired workers from eight companies and three construction trade unions into a prospective study investigating the development of carpal tunnel syndrome (CTS) and other UE MSDs. None of the companies used POPP screens as part of their hiring practices. Eligible subjects were at least 18 years of age and worked at least 30 h/week. Subjects were excluded if they had a past diagnosis of CTS or other upper extremity peripheral neuropathy, had a pacemaker or internal defibrillator, or were pregnant at time of enrollment. Study participants ($n = 1{,}107$) were enrolled between July 2004 and October 2006, and completed self-reported questionnaires at baseline and at 6, 18 and 36 months post-enrollment. Physical testing was performed at baseline on all subjects; a subset of the original cohort ($n = 458$) completed repeat physical testing at 36 months. Details of the recruitment and enrollment methods have been described in previous articles [19, 20]. The study was approved by the Institutional Review Board of Washington University in Saint Louis; all subjects provided written informed consent and were compensated for participation.

Information gathered through self-reported questionnaires included subjects' medical history of chronic disorders, acute injuries, and physician diagnosed musculoskeletal disorders of the upper extremities such as sprain, strain, tendinitis, rotator cuff injury, thoracic outlet syndrome, and wrist ganglion cyst. Work-related information included current company; job title and associated work exposures; and limitations in work performance including reduced productivity rate, job restrictions, missed work days, limited ability to work, and change of job at the same company or changed companies. Self-reported upper extremity symptoms were rated on a 0–10 point scale, with 10 equivalent to maximal pain. Severe upper extremity symptoms were defined as pain rating of five or more on the 10 point scale [21].

Physical testing by a trained technician evaluated the presence of upper extremity signs of MSDs bilaterally at the elbow, wrist, and hands by inspection, palpation, and provocative maneuvers. Weight, height, wrist anthropometrics, and bilateral upper extremity nerve conduction studies were measured. Grip strength was measured using a Jamar dynamometer (North Coast™ Hydraulic Hand Dynamometer, Morgan Hill, CA) with the handle in the second smallest setting, following the testing procedures for the norm tables produced by Mathiowetz et al. [22]. The participant's elbow was positioned at 90° and held close to the body, with the wrist in slight extension; the technician instructed the subject to squeeze the dynamometer until maximal force was achieved [22, 23]. Peak force was recorded. Three trials were collected per hand with at least 20 s between each trial. The mean of the three peak trials was computed. Prior studies have shown the Jamar dynamometer was a reliable instrument for inter-rater reliability and test–retest reliability [22, 24–27].

We evaluated three different outcomes: (1) prevalent upper extremity symptoms of the shoulder, elbow or wrist/hand with a rating of at least 5/10 level on the symptom severity scale [28], (2) work disability defined as a limitation of work performance on one or more of six indicators (decreased productivity rate, job restrictions, missed work days, limited ability to work, change of job at the same company, or changed company), and (3) self-reported physician diagnosed MSD of one or more conditions of the upper extremity including tendonitis of the elbow, wrist or hand, rotator cuff injury, thoracic outlet syndrome, shoulder bursitis, lateral or medial epicondylitis, ulnar neuritis, wrist bursitis, ganglion cyst, Dequervain's syndrome, carpal tunnel syndrome, or trigger finger.

Analyses examined grip strength as a predictor of these three outcomes. We used the average grip of three trials in analytic models by two forms: (1) grip as a continuous variable and (2) grip categorized into three strength levels based on gender and age-based normative data [22, 29]. To categorize grip values for the second set of models, we compared the mean right hand grip score to the norm distribution of the appropriate gender and age range, and selected the appropriate category: (1) within one standard deviation (SD) of the normative value, (2) more than one SD above the norm value, or (3) more than one SD below the norm. We controlled for other variables in the models that have been associated with either the health outcome or grip strength. These included age, gender, body mass index, job category, presence of upper extremity symptoms at time of baseline testing, prior history of upper extremity MSD or past medical diagnoses of diabetes, arthritis, thyroid disease, gout, or fibromyalgia. We classified jobs into three categories based on job title and industry classification. The three categories were construction trades (sheet metal workers, floor layers, and carpenters), service workers (housekeepers, food service workers, groundskeepers and maintenance workers, and hospital technicians involved in patient lifting), and office/technical workers (computer workers, laboratory workers, engineers, and clerical workers).

For the primary analysis, we used multivariate logistic regression models to examine associations between baseline grip measures and three separate health outcomes while controlling for personal and work factors. We analyzed these associations between baseline grip and health outcomes at three time-points post-enrollment: 6, 18 and 36 months. We restricted all analyses to the right hand so the grip strength measures, the side-specific outcomes (symptom severity and UE MSD diagnoses), and prior UE MSD diagnosis all referred to the same side of the body. For a subset of the workers that received physical exams at baseline and the 3 year time point, we evaluated whether grip strength levels had significantly changed over time within job categories. Given the longitudinal design of our study, we tested for possible effects of survivor bias in the results by evaluating differences in baseline characteristics for subjects lost to follow-up and for subjects who changed jobs unrelated to symptoms. All analyses were performed using SPSS version 16.0, SPSS Inc., Chicago, IL; statistical software [30].

Results

The newly-hired cohort of 1,107 workers was relatively young, with a mean age of 30 years; 65 % were male gender (see Table 1). The largest portion of subjects had been recently hired into the construction industry (40 %), followed by service (30 %) and office/technical workers (29 %). Mean and range of ages were slightly lower for the construction workers (mean 26 years, range 18–52) compared to the service workers (mean 33 years, range 18–66) and clerical workers (mean 33 years, range 19–63). Using Mathiowetz's norms to categorize hand strength values accounting for age and gender, results showed that a larger than expected proportion of the cohort, 26 % of males and 20 % of females, were assigned to the lowest grip category of more than one standard deviation below the norm [22]. The proportion of subjects in the high grip category (8.5 % overall) is lower than the expected level of 16 % from the normal distribution of the Gaussian curve.

Results from all regression models are presented in Table 2. We ran multivariate regression models for outcomes of severe symptoms and work disability, but were limited to univariate analyses for the outcome of physician diagnosed MSDs due to the low case count. Only one of the models (6 months with the Severe UE symptoms outcome) showed that grip was predictive: stronger baseline hand grip was associated with a *higher* prevalence of symptoms at 6 months (odds ratio 1.79, 95 % CI 1.11–2.89, p value 0.02). Note that this association is opposite to the hypothesized direction of the effect. In most models, prior diagnoses of musculoskeletal disorders and baseline industry categories were associated with greater prevalence of work disability and UE symptoms. Some models showed a meaningful association with medical comorbidities (such as diabetes and arthritis) and with female gender. Increased age was significant in one model. We ran all models with grip entered as a continuous variable and found no associations between grip and any outcome, although there were similar significant associations found with the covariates (data not shown). To control for potential effects related to job changes, we repeated all models restricted to subjects who remained in the same job until the 3 year follow-up time point; these analyses showed no difference in results compared to the total cohort. Since we restricted the analyses to the right upper extremity, subjects who were left hand dominant were

Table 1 Baseline characteristics of the cohort (n = 1,107) and outcome frequencies stratified by gender

	Male (n = 719)		Female (n = 388)		Total (n = 1,107)	
	Mean	SD	Mean	SD	Mean	SD
Age (years)	28.8	9.4	33.2	11.2	30.3	10.3
Body mass index (kg/cm^2)	27.7	5.4	29.9	8.1	28.5	6.6
Right mean grip (in kg)	50.2	8.9	31.1	6.1	43.5	12.1
	n	(%)	n	(%)	n	(%)
Job category[a]						
Construction	447	62.2	4	1.0	451	40.7
Service	155	21.6	177	45.6	332	30.0
Office/technical	117	16.3	207	53.4	324	29.3
Right hand dominant	635	88.3	345	88.9	980	88.5
Right hand grip						
Below 1 SD	183	25.6	77	20.0	260	23.6
Within 1 SD	482	67.4	264	68.6	746	67.8
Above 1 SD	50	7.0	44	11.4	94	8.5
Past medical diagnoses[b]						
Diabetes	14	1.9	12	3.1	26	2.4
Thyroid	4	0.6	22	5.7	26	2.4
Arthritis	20	2.8	15	3.9	35	3.2
Fibromyalgia	2	0.3	3	0.8	5	0.5
Gout	6	0.8	2	0.5	8	0.7
Past right UE MSD diagnosis	141	19.7	49	12.7	190	7.2
Tendinitis distal arm	18	2.5	14	3.6	32	2.9
Tendinitis shoulder	15	2.1	6	1.6	21	1.9
Rotator cuff	25	3.5	3	0.8	28	2.5
Ganglion cyst	6	0.8	7	1.8	13	1.2
Sprain/strain distal arm	88	12.3	23	5.9	111	10.0
Sprain/strain shoulder	59	8.3	11	2.8	70	6.4
UE symptoms baseline	240	33.4	91	23.5	331	29.9

SD standard deviation, *UE MSD* upper extremity musculoskeletal disorder

[a] Construction (sheet metal workers, floor layers, and construction workers), Service workers (housekeepers, food service workers, and hospital technician involving patient lifting, groundskeeper and maintenance workers), and Office/technical workers (computer workers, laboratory workers, engineers, and clerical workers)

[b] Includes one or more of the following diagnoses: tendonitis of the upper extremity, rotator cuff injury, thoracic outlet syndrome, shoulder bursitis, lateral or medial epicondylitis, ulnar neuritis, wrist bursitis, ganglion cyst, Dequervain's syndrome, carpal tunnel syndrome, or trigger finger

analyzed using their right hand grip measures. We re-ran all models restricted to subjects with right hand dominance (n = 908, 88.5 %) and found similar results with only one model showing a significant positive association between having high grip strength and severe symptoms at 6 months—again in the opposite direction to that predicted (odds ratio 1.72, 95 % CI 1.04–2.86, p value 0.04).

We explored the change in grip strength over time within each job group and found that there was a significant increase in strength at follow-up (n = 481, baseline 44.9 kg, 3 years 49.9 kg, t test 15.76, $p < 0.001$) and that these differences occurred in all job categories (proportion in high grip category at baseline versus follow-up: construction 8 vs. 30 %, service 10 vs. 14 %, office/technical 17 vs. 27 %). At baseline, the proportion of workers in each grip category was similar (proportion in low grip category: construction 21 %, service 27 %, office/technical 21 %). All groups had increased report of symptoms over time with the largest change among the service workers (baseline vs follow-up 18 vs. 41 %) compared to construction (39 vs. 46 %) and office/technical (31 vs. 39 %).

We explored possible survivor effects in our results. For cases lost to follow-up, we compared differences in gender,

Table 2 Multivariate logistic regression analysis results for three health outcomes for all subjects at three time points

	6 months			18 months			36 months		
	Severe UE symptoms (n = 961) OR (95 % CI)	Work Impairment (n = 944) OR (95 % CI)	Diagnosis of UE MSD (n = 969) OR (95 % CI)	Severe UE symptoms (n = 926) OR (95 % CI)	Work Impairment (n = 912) OR (95 % CI)	Diagnosis of UE MSD (n = 932) OR (95 % CI)	Severe UE symptoms (n = 876) OR (95 % CI)	Work Impairment (n = 868) OR (95 % CI)	Diagnosis of UE MSD (n = 884) OR (95 % CI)
Grip									
Below 1 SD	0.99	1.13	1.27	0.77	0.80	1.06	0.92	0.72	1.27
	(0.70–1.42)	(0.74–1.72)	(0.38–2.14)	(0.54–1.10)	(0.53–1.22)	(0.54–2.09)	(0.64–1.32)	(0.46–1.13)	(0.65–2.50)
Within 1 SD	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Above 1 SD	1.79	1.73	2.15	0.94	1.21	1.18	1.06	1.38	1.62
	(1.11–2.89)*	(0.99–3.00)	(0.85–5.46)	(0.57–1.55)	(0.69–2.13)	(0.48–3.11)	(0.63–1.78)	(0.78–2.44)	(0.65–4.04)
Covariates									
Age (year)	1.01	1.00		1.02	1.02		1.00	1.01	
	(1.00–1.03)	(0.98–1.02)		(1.00–1.04)*	(1.00–1.03)		(0.98–1.02)	(0.99–1.03)	
BMI	1.10	1.09		1.04	0.97		1.09	1.01	
(per kg/cm^2)	(0.97–1.25)	(0.94–1.27)		(0.92–1.18)	(0.84–1.12)		(0.96–1.23)	(0.88–1.18)	
Gender (ref: male)	1.55	1.70		1.59	2.14		2.05	1.41	
	(1.05–2.30)*	(1.04–2.78)*		(1.09–2.33)*	(1.34–3.43)*		(1.35–3.11)*	(0.87–2.29)	
Past medical history[a]	1.76	1.52		1.44	2.16		1.71	1.98	
	(1.04–2.97)*	(0.82–2.81)		(0.8–2.43)	(1.23–3.79)*		(0.98–2.96)	(1.08–3.62)*	
Prior MSD diagnosis[b]	1.79	1.90		1.48	1.89		1.65	1.96	
	(1.25–2.56)*	(1.27–2.84)*		(1.03–2.13)*	(1.26–2.82)*		(1.14–2.39)*	(1.29–2.99)*	
Job category									
Office/technical	Reference	Reference		Reference	Reference		Reference	Reference	
Service	0.84	1.16		1.06	1.81		1.79	2.93	
	(0.5 7–1.24)	(0.72–1.88)		(0.73–1.54)	(1.16–2.84)*		(1.20–2.67)*	(1.80–4.75)*	
Construction	1.61	2.26		1.53	2.66		3.06	2.94	
	(1.04–2.51)*	(1.30–3.91)*		(1.00–2.37)	(1.54–4.62)*		(1.90–4.93)*	(1.65–5.26)*	

UE MSD upper extremity musculoskeletal disorder, *OR* odds ratio, *CI* confidence interval, *SD* standard deviation, *BMI* body mass index

* Significant results based on a p value <0.05

[a] Includes diabetes, arthritis, thyroid disease, gout, or fibromyalgia

[b] Tendinitis of shoulder or distal arm, rotator cuff disorder, ganglion cyst, or sprain/strain of shoulder or distal arm

age, and baseline grip strength and found no differences to those who remained in the study. The proportion of subjects in the baseline job categories showed a larger proportion of drop-out from the service group and a smaller drop-out rate from the office/technical group. We also looked at whether those lost to follow-up had previously reported difficulties in work performance for the factors in the work disability outcome (decreased productivity, job restriction, lost work time, limited ability to work, and change of job or company) and found no differences to those that remained in the study for 3 years.

Discussion

Our results found no consistent association between grip strength and health outcomes during 3 year follow-up of newly employed workers. This precludes our ability to accept the hypotheses that high grip strength is protective, and that weaker workers are more likely to experience upper extremity symptoms, work disability, or an UE MSD diagnosis. Job category and previously diagnosed upper extremity MSD consistently predicted future health outcomes with large effect sizes. Many workers changed jobs during this period of time, but the results did not differ for those that remained in the same job. Workers re-tested after 3 years showed higher average grip strength, with the greatest increase among workers in the most hand-intensive jobs. This change was not associated with symptoms.

Physical strength is an important characteristic for workers who perform physically demanding jobs. The workers in this study self-selected into jobs in different industries. It is interesting to note that a large number of the workers in each job group had weak grip by population norms at baseline. Within the construction group, the average grip scores were well below those described in widely used national norms for males of the same age. Other studies have shown similar low levels of strength in workers [17, 31]. The workers in all groups were relatively young so they may not have achieved their lifetime peak potential strength. A large number of the workers with repeated grip values showed an increase in strength after 3 years of work. This suggests that screening hand strength in young workers who have not reached their maximal strength may not be useful in predicting long-term health outcomes; strength at the start of employment was not predictive of future health or work outcomes for any group in our study. Workers with less hand strength may use alternative work methods to reduce physical stress, particularly in jobs with greater demands. Further studies should explore what factors help workers with low hand strength avoid symptoms, but leave those with greater strength at increased risk of symptom development.

As shown in previous studies, past diagnosis of MSD was the strongest predictor of future symptoms or work disability [32]. This strong association between past and future symptoms or illnesses overshadowed potential benefits from higher strength. Workers in physically demanding jobs who have a history of MSDs are at increased likelihood of developing future symptoms or work disability.

Our study found POPP testing of grip strength was not predictive of UE symptoms, work disability, or diagnosis of a UE disorder. This held true even among construction workers, who had the most physically demanding work tasks and were at the greatest risk of symptoms and disability. Our findings are consistent with one study conducted in 2005 of 2000 workers, which found that muscular strength and physical capacity alone were not predictive of future musculoskeletal injuries [17]. This study did report that rates of sprains and strains in all body parts were higher among the small number of workers whose physical capabilities were "mismatched" to their jobs based on lifting requirements. Overall, there are few high quality studies of the very common practice of POPP screening: based on existing studies, a Cochrane review of pre-employment examinations for preventing occupational injury in workers [33] and a systematic review for investigating the relationship between physical capacity and musculoskeletal health problems of the low back and neck/shoulder [18] were unable to draw any conclusions about the relationship between worker physical testing and risk of future musculoskeletal disorders. POPP exams are a popular strategy among employers—a 1998 study estimated that half of workers in the US underwent a POPP exam [34]. The popularity of POPP exams despite minimal evidence for their effectiveness has led one author to comment that "The use of pre-employment examinations is often driven more by cultural practices than evidence" [35].

The strengths of this study were the wide range of hand-intensive jobs, the large number of newly hired workers in a variety of industries, and use of several different outcomes for comparison of results. The limitations were the relatively brief follow-up period of 3 years, relatively young age of the cohort with potential for increasing natural strength, and incomplete follow-up of all workers. The limited time for follow-up in combination with the relatively young cohort may not have been long enough for many workers to experience or produce symptoms. It may be that using grip strength as a predictor of symptoms would be more apparent among older workers, but there is at present no published data to support this hypothesis.

Conclusions

Hand strength did not predict injuries or symptoms in a group of newly hired, predominantly young workers regardless of the physical demands of their jobs.

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Conflict of interest The authors declare that they have no conflict of interest.

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